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A PHOTOELECTRIC SEED COUNTER

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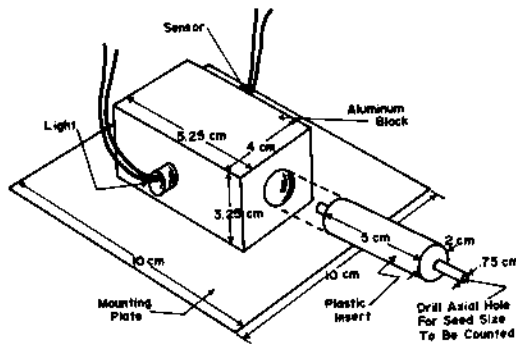


Fig. 2. Sensor assembly

mary control unit, depending upon the control function exercised.

In the authors' model, this control signal is used to deactivate a solid state relay which controls a 115-VC load, but almost an unlimited number of possibilities for control exist, and the actual device used or function exercised will depend upon the particular application.

A reset button clears the accumulated count from the decade counters and resets the control memory unit after the data have been recorded, preparing the instrument for another count.

The sensor assembly is shown in Fig. 2. The metal block and mounting plate are made of aluminum and the insert is machined from clear acrylic plastic. The only critical considerations in constructing the sensor are that the light and photodiode must be axially aligned on a diameter of the larger hole in the block at a distance of no more than about 2 cm, and the hole through the plastic insert must be drilled so that the inside is clear, allowing maximum transmission of light. Scoring the inside surface of this conveying tube will render the entire sensor inoperative.

The inside diameter of the hole through the plastic insert is determined by trial and error. This is drilled to the machinist's number drill size that is the minimum diameter which will let a particular type of seed pass. A pilot hole should be drilled through the insert at least two number sizes smaller than the desired hole to allow water cooling of the bit when drilling the finished hole. This prevents heat scoring of the inside surface of the hole. The outside diameter of the nipples protruding from either end of the insert is slightly larger than the inside diameter of the flexible plastic tubing closest to the diameter of the seeds being counted.

To date, the authors have developed inserts for counting alfalfa (*Medicago sativa* L.), onions (*Allium*), and radishes (*Raphanus raphanistrum* L.), which work very successfully.

With large irregular seeds, such as beans (*Phaseolus vulgaris* L.) and corn (*Zea mays* L.), the plastic insert is not used, but instead a piece of 5-mm (3/8-inch) inside diameter (ID) plastic tubing is inserted completely through the sensor. The outside diameter (OD) of the tubing is increased to the inside diameter of the hole in the sensor with two bands of masking tape, thus centering the tube inside the sensor. Two coils approximately 20 cm in diameter are made around the

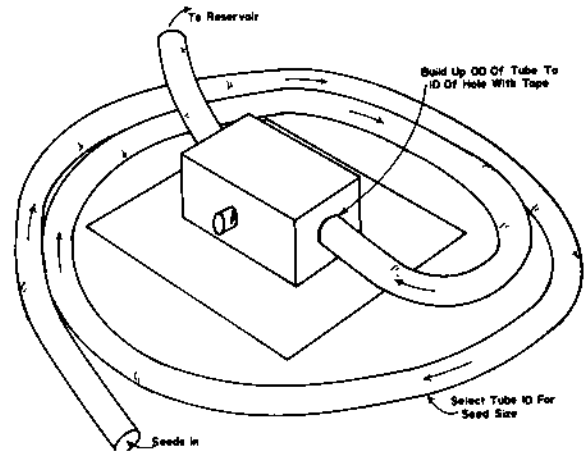


Fig. 3. Sensor assembly with tubing for large, irregular seeds.

sensor with the tubing before the tubing enters the counting unit. This circular path orients the seeds in the direction of their long dimension and forces them to travel against the outside surface of the tube approximately half-way up the diameter, thereby insuring that some part of each seed will cross between the light and photosensor. If a seed becomes lodged across the pickup tube, it is quite easy to squeeze the tube and dislodge it. All types of beans, ranging from small pea-beans to large pintos, have been successfully counted with this arrangement. Corn requires a slightly larger 1.25-cm ID (1/2-inch) hose; small irregular seeds such as wheat (*Triticum aestivum* L.) may be successfully counted with a piece of tubing about 0.3-cm (1/8-inch) ID. With the smaller tubing, it is important that the plane of the arc in the last section of tubing be parallel with the plane between the light and photodiode to insure that the seed passes between these devices.

This counter can be interfaced to commercially available vibratory seed separators by constructing a trough of clear plastic with the photodiode positioned in the bottom and the light mounted directly above it at a distance of about 2 cm. This trough is placed at the end of the separatory helix at an angle so that the seeds will slide down it easily but not so fast that they begin to bounce. Bouncing is still a problem with some light, irregular seeds such as onion, and a different type of sensor may have to be constructed. A vacuum pickup could be used with this separator by positioning the end of the pickup hose at the end of the separatory helix; however, this is like gilding the lily.

For operation, connecting tubes are attached to both ends of the sensor insert (or one continuous tube used in the case of irregular seeds), and then attached to a reservoir which can be anything from a laboratory vacuum flask to a specially constructed cylinder with foam padding in the bottom to absorb the impact of the seeds. The seeds are placed in a large screened-bottom pan and shaken to make them separate (a laboratory soil sieve works well). A solid bottomed pan is much less desirable because the air-flow is along the surface of the pan and then into the tube rather than coming directly upward through the screen into the tube. This flow along the bottom of

the pan tends to pull in surrounding seeds that clog the tube or perhaps pass 2 together through the tube so they are only counted as one seed.

The vacuum applied to the system is adjusted so that seeds are easily picked up by the tube, but is not so high that surrounding seeds are also moved into the tube. This vacuum level depends on the particular seed being counted and the size of the mesh in the screen. A vacuum cleaner satisfactorily supplies vacuum to pick up such large seeds as beans and corn, but a pinch-clamp must be used on the vacuum line to reduce the airflow when counting smaller seeds such as onions, alfalfa.

There are several commercially available seed counters that operate on approximately the same general principles as the unit outlined in this paper. They have, however, several disadvantages. They cost about \$1500 to \$2500 each, while the unit described here should not exceed \$300, even if housed in a relatively expensive case.

The operation of most commercially available seed counters appears to be based upon the work of Kramer and Decker (2); a bowl feeder is used to feed seeds down a tube containing a photoresistor and lamp assembly. Total count is accumulated on an electromechanical counter and the sensitivity of the input amplifier is adjusted for the seed size.

Several problems arise from this design. The rise and fall times of the specified photocells are about 2 to 6 ms, and seeds arriving at the sensor closer than 4 to 12 ms apart would not be resolved as 2 separate output pulses. These photocells are sensitive to ambient light levels, and hence, the sensor must be shielded to prevent interference. The major limiting factor on counting rate is the electromechanical counter which has a cycle time of approximately 40 ms. One major complaint from users of these counters is that the sensitivity adjustment for counting seeds of various sizes seems to be quite difficult to manipulate. This restricts the counter to use with one seed size or use by a person who has a good "feel" for this adjustment.

The counter outlined in this paper overcomes these problems through use of different components. Instead of the photoresistor, a photodiode is used as the sensing device that permits seeds spaced at 100 μ s or longer to be resolved as separate pulses. This photo-

diode is not affected by ambient light levels, so both sensor and lamp can be completely exposed, if desired. Because counting and display are performed electronically, the maximum count rate is about 250 KHz, which makes the rise and fall times of the photodiode the limiting factor in time resolution of seeds. Once the light and photodiode have been aligned at the correct distance, no further calibration is necessary.

The problem then becomes the mechanical one of insuring that some part of each seed passes between the light and photodiode. In the authors' model, this problem was solved by machining interchangeable inserts with the right diameter axial hole for the sensor so that the seeds had to pass between the light and sensor. All that is necessary to change from one seed size to another is simply to select the correct size insert for the seed to be counted or, in the case of irregular seeds, replace the insert with a piece of tubing passing through the sensor. Mounting the sensor and light assembly on a V-shaped trough may make an assembly that will count seeds ranging in size from pinto beans to alfalfa without having to adjust anything. This is presently under investigation.

LITERATURE CITED

1. Operation of the MK5002P MOS 4-Digit Counter Decoder. 1971. Mostek Corporation Operation Note, Carrollton, Texas.
2. Kramer, H. A., and R. W. Decker. 1962. Electronic Seed Counter. *Agr. Eng.* 43:346-348.

PARTS LIST*

- 1 - Mostek MK5005P Counter/Decoder
- 1 - Motorola MC3401P Quad Op. Amp.
- 1 - Hewlett-Packard 5082-7405 LED Readout
- 1 - Beckman 899-3-R220 Resistor Array
- 1 - California Electronic 22-100-512 Power Supply
- 7 - 2N5447 Transistors
- 4 - Motorola MPS-A13 Darlington
- 1 - Texas Instruments H-11 Photodiode
- 2 - 1N628 diodes
- 3 - 10K Ω 1/4 W 10% resistors
- 1 ea. - 100 Ω , 1K Ω , 68K Ω , 100K Ω 1/4 W 10% resistors
- 1 ea. - 0.1mf 10V, 1.0mf 50V capacitors
- 1 - SPST N.O. pushbutton switch
- 1 - 24-pin DIP socket
- 3 - 14-pin DIP sockets
- 1 m - Belden 8444 4-conductor cable

*Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the U. S. Department of Agriculture.